

PHOTOGRAMMETRIC RESTITUTION OF A PRESUMED ANCIENT ASCLEPIUS TEMPLE IN TITANI, PELOPONNESOS, GREECE.

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ABSTRACT

Close range photogrammetry is a useful tool for the documentation and registration of archaeological sites. In this case study, photogrammetric restitution was applied to a presumed ancient Asclepius temple in Titani, Peloponnesos, Greece. The archaeological remains that were recorded and processed in this research are small parts of walls and wall foundations, mostly made out of irregular shaped stones. The fragmentary remains and the need to record both the façades of the stones as well as the upper surfaces, complicate the photogrammetric recording and processing workflow.

The use of 3D information is important for the documentation, conservation and possible further excavation of the site. Stereographic pictures in combination with terrestrial topographic measurements were processed in photogrammetric software. The stereo photographs were taken by a non-metric high resolution digital single lens reflex camera with a minimum overlap of 65%. Targets placed on the remains of the walls were measured by total station to obtain ground control points for the orientation of each 3D stereo model in an absolute coordinate system (HGRS'87). The photogrammetric processing of the stereo models resulted in very accurate digital elevation models and orthophotos of the walls. Further combination of these final products and merging these products in a visualization and analysis software (like a CAD or GIS) leads to a 3D presentation of the archaeological excavation, which can be further used to evolve this archaeological site and give a better understanding of the site. Moreover, topographical measurements and photomodelling were applied to record the site.

INTRODUCTION

There is still a growing awareness of the need for a thorough conservation of important cultural heritage sites all around the world. For the conservation and management of archaeological or cultural heritage sites, sufficient and accurate 3D information is necessary. The acquisition of accurate 3D models or 2D plans of archaeological sites, cultural heritage sites and monuments allow a cultural or site management based on correct, complete and geometrically accurate documents. The research presented in this paper gives an overview on the different 3D measurement techniques that have been used to document the archaeological site of Titani, in the Peloponnesos region in Greece (Figure 1).

The most efficient measurement technique to measure the different parts of the site depends on the specific field conditions, the types of objects and the required accuracy of the deliverables. Therefore, different measurement techniques (total station, GNSS, photogrammetry) were used and combined, depending on the different factors. Moreover, new measurement techniques like photomodelling and laser scanning have been tested during different fieldwork campaigns. The importance of this 3D information was proven by a partial collapse of a wall on the site between two fieldwork campaigns. The metric documentation recorded before this collapse gives a clear and accurate 3D representation on how the wall was constructed. Because the conservation of the archaeological site is endangered by natural erosion, tree roots on top of the acropolis that push

the stones of the walls aside and the use of the site by the village people as grazing area for their goats and sheep, the 3D documentation offers the base for further conservation and restoration.

The documentation of the archaeological site in Titani is part of a research program initiated by the Belgian School at Athens in 2004 (Dr Christiane Tytgat), in collaboration with Ghent University, Department of Geography (Belgium). The fieldwork campaigns in 2004, 2005 and 2006 focused on identifying the location of the sanctuary of Asclepius, the extents of the city over the centuries and the recording of all visible archaeological remains. Therefore, a new topographical map of the site and its surroundings was produced, together with a detailed digital terrain model, orthophotos and a study of the land use in the region. The fieldwork campaigns in 2010 and 2011, as part of the collaboration between Ghent University and the Netherlands Institute at Athens (also with Dr Christiane Tytgat) complemented the previous measurements and documentation. The topographical map of the site and its surroundings was completed and extended. Besides, new excavations were very accurately recorded and added to the maps. Moreover, new 3D measurement techniques such as laser scanning and photomodelling were applied to complement the already existing 3D models and orthophotos. In 2011, the field measurements also focused on the complete 3D recording of the wall foundations of the presumed ancient Asclepius temple.

In the following chapter, more background information about the archaeological site of Titani will be given. The historical importance of the site and the remnants that can still be found on site will be further detailed. Secondly, the different 3D measurement techniques will be discussed. First, the topographical measurements will be explained, together with the laser scanning of a part of the remnants. Thereafter, the use of digital photogrammetry will be explained, followed by the application of structure from motion. The paper ends with some conclusions, based on the extensive use of different 3D measurement techniques on the site of Titani.

ARCHAEOLOGICAL SITE OF TITANI

The village of Titani, including the archaeological site, is located about fifty kilometer south-west of Corinth, in the Peloponnesos region (Greece) (Figure 1). The site of the ancient Titani was formally identified by L. Ross in 1840, but has remained a mostly unexplored site so far. Based on historical documents, it can be concluded that this was a very important site in the region in antiquity. Titani was well known for its sanctuary for Asclepius, one of the earliest centers for practical medicine. These medical centers dedicated to Asclepius reached their peak during the 4th century BCE (1). The ancient traveler Pausanias described this sanctuary in detail, but considered it already as ancient at the time of his writing (2nd Century CE).



Figure 1: Location of Titani (mapsof.net, 2012)

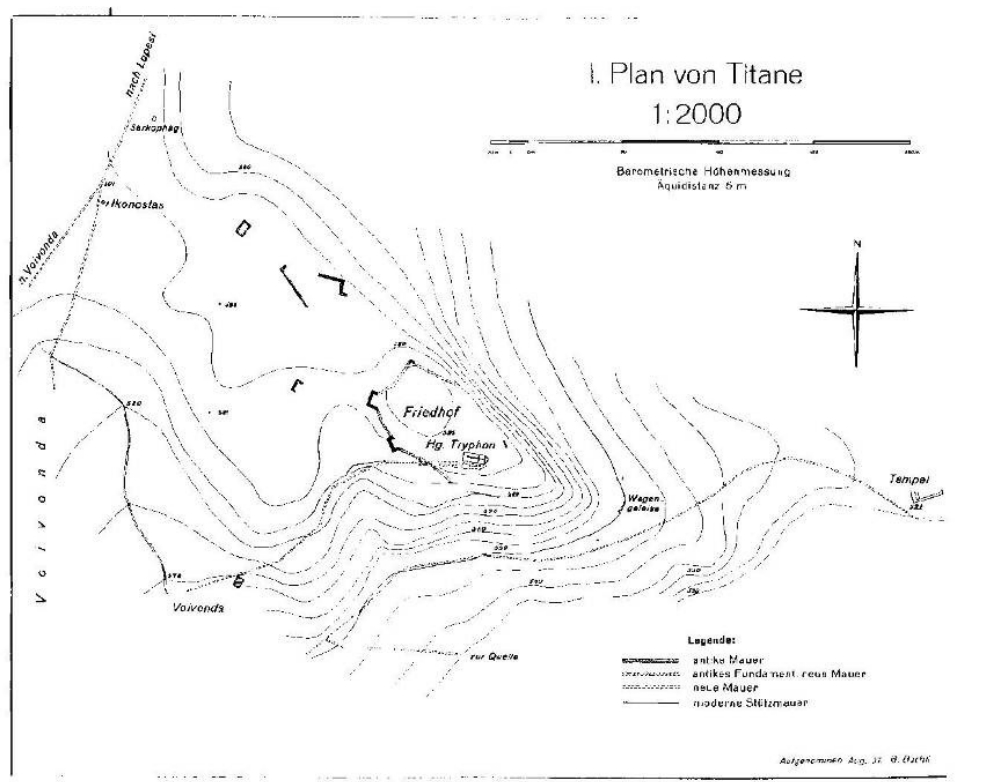


Figure 2: Plan of the site of Titani (E. Meyer, 1937)

E. Meyer was the first to perform fundamental research and mapping of the site in 1937 (2). The map of the site based on his research was until now still used by researchers working on this site (Figure 2). The site consists of two large parts. On top of the acropolis, there are remnants of walls surrounding the acropolis. These remnants are still in a relatively good conservation stage. However, in 2006, a small part of this wall collapsed, confirming the urgent need of conservation actions and accurate 3D recording and documentation. These wall remnants are built with irregular shaped stabled stones, but the two towers of these remnants consist of larger rectangular shaped stones (Figure 3, left). The second part of the site is the lower plateau, separated from the acropolis by a precipice. On this lower plateau, a lot of individual stones are still present, together with the foundations of the presumed ancient Asclepius temple (Figure 3, right).

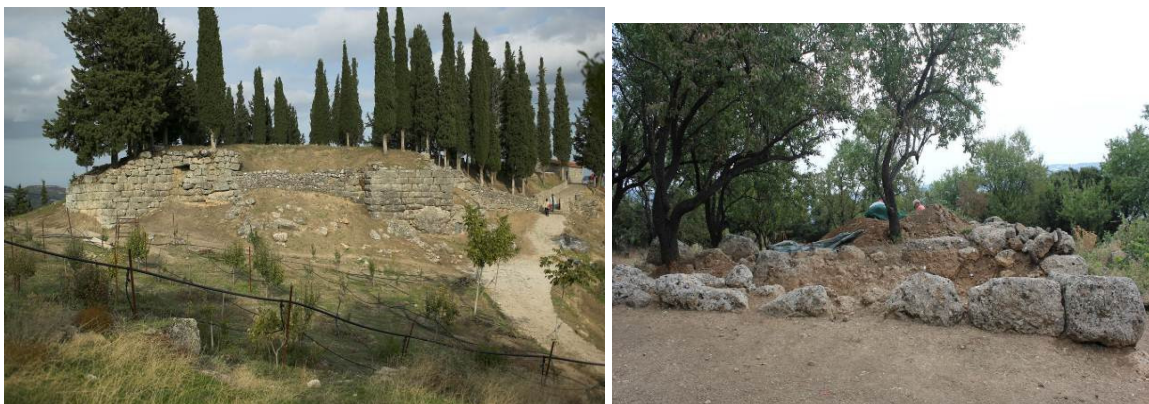


Figure 3: Remains of the walls on the acropolis (2010) (left); Excavation of the foundations of the presumed temple on the lower plateau (2011) (right)

3D ACQUISITION TECHNIQUES

Topographical measurements

The recent topographical measurements on the site of Titani mainly provide the necessary accurate topographical information for a new detailed map of the site and its surroundings, together with the necessary 3D points for a detailed digital terrain model of the area. Next to these topographical measurements of the terrain, other topographical measurements were performed to obtain accurate 3D coordinates of the ground control points used for the close range photogrammetry. During the consecutive fieldwork campaigns, a number of permanently materialized reference points were used to integrate all measurements in the same coordinate system. Based on GPS measurements and a geodetic reference point on top of the acropolis, all measurements were positioned in the Greek HGRS'87 coordinate system. During every field campaign, the topographical measurements aimed to complement the previous measurements or to intensify the topographical information in certain areas of interest.

Additionally, in 2010 the steep slope between the acropolis and the lower plateau was measured with the scanning function of a Trimble S6 Robotic Total Station. The scanning of this slope was an alternative method to obtain the necessary topographical information needed for the digital terrain model because the steep slope was not directly accessible for a surveyor.

In 2011, the topographical measurements focused on the detailed recording of the new excavations on the lower plateau. Not only the necessary ground control points for the photogrammetric processing were measured, but also the remnants of the wall foundations were measured stone by stone (Figure 4). These detailed measurements include the top and bottom edge of each stone and the important features of the different excavations.

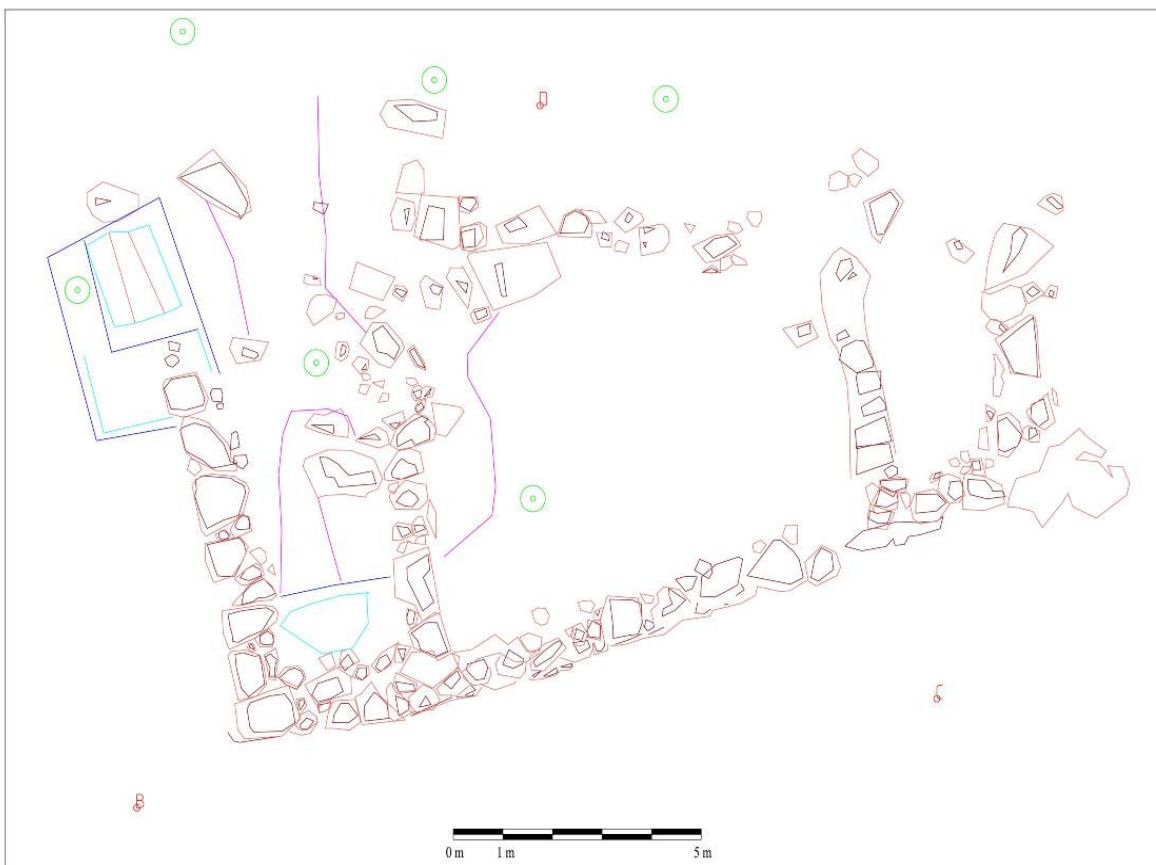


Figure 4: Topographical measurements of the presumed ancient Asclepius temple (2011)

Digital photogrammetry

During the consecutive fieldwork campaigns in Titani, the different parts of the archaeological site were recorded with close range digital photogrammetry. Close range photogrammetry is the term being used when dealing with small distances between the object and the camera position, which is generally the case in terrestrial applications. Digital photogrammetry is a very useful technique for recording complex 3D shapes, certainly when they are located on rough terrain where it is hard to set up a total station or other measurement instruments. Nevertheless, it was still a challenge to find sufficiently good camera positions to photograph the different remnants. Taking into account the necessary overlap and the direction of the camera for recording the images, the ideal camera positions were not always accessible on the field. Moreover, the trees on site and the constantly changing lighting conditions and shadow areas required a good planning and sometimes creative solutions to avoid too large contrasts in the images. The recorded photographs, together with the topographically measured ground control points resulted in digital elevation models and further derived orthophotos (3).

Light cardboard signals were placed on the walls to act as ground control points for the absolute orientation of the photogrammetric models (Figure 5). The signals were placed on the stones so that there are at least six signals visible in the overlapping area of each photographed stereo model. These signals are about 5 x 5 cm large, with the diagonals forming a black cross to indicate the center of the ground control point. These points are measured with total station to obtain the coordinates in the Greek HGRS'87 coordinate system. It was chosen to stick artificial ground control points to the walls instead of using characteristic points on the walls to avoid mistakes during ground control point identification in the software. After a few days of rain, the light cardboard signals will disappear from the stones, leaving no damage to the archaeological remains.



Figure 5: Part of the remnants with cardboard ground control points (2011)

The pictures were taken with a digital single lens reflex camera Canon EOS 1Ds (11 Mpx). This is a non-metric camera, with limited lens distortions and no fiducial marks on the image so that there is no interior orientation needed during the photogrammetric processing. The advantage is that this type of camera is lighter, easier to use and cheaper, so more commonly accessible than calibrated photogrammetric cameras. But even with such type of camera it is possible to obtain very accurate photogrammetric results. To build up the stereo models of the remnants, each part was photographed from two different positions with a minimum overlap of 60%. In addition, the precondition of having at least six ground control points in each overlapping area has to be taken

into account (4). To reduce the possible errors during processing, the pictures were taken while avoiding direct sunlight and big shadow parts on the walls and places with little or no contrast. Specifically to photograph the upper side of the remnants on the excavation site, the camera was held in hand while standing on a ladder or the camera was mounted on an extended tripod which could be held higher up in the air.

The photogrammetric processing was performed with the VirtuoZoTM software. As stated above, the images were taken with a non-metric camera, no interior orientation was performed. In the relative orientation, homologous points between both images of the stereo model are identified. In this step, the RMSE was limited to 1/5 of a pixel. Typical pixel sizes are between 0.5 and 1 mm (real world values) on the images which were processed in this project and these images were taken from 2 to 3 m distance. In this overlapping area of the stereo model, at least 150 points are identified before the absolute orientation and image matching step are performed. For the absolute orientation, at least six ground control points are used for each stereo model. The identification of these points in the stereo model locates and orientates this model in the Greek HGRS'87 coordinate system. The Root Means Square (RMS) errors for the absolute orientation in X, Y and Z are between 1.1 cm and 1.7 cm. The quality of the image matching is indicated by colored 'pegs' (Figure 6). Red pegs indicate a bad matching and green pegs indicate a good matching. As can be seen on Figure 6, the stones of the remnants give a good matching, where the space between the stones doesn't result in a good matching (5).

After the image matching, the digital elevation models and orthophotos are automatically generated, based on a ground sampling distance and resampling method, as set by the operator. For the digital elevation models, the RMS averaged for all stereo models is 1.0 cm after outlier removal. The ground sampling distance for the elaborated elevation models and orthophotos is set at five mm, which means that there is a Z-value calculated for a 5 mm raster in X and Y. All these settings and the errors for the different processing steps are summarized in a 'Quality Assistance' report for each stereo model.

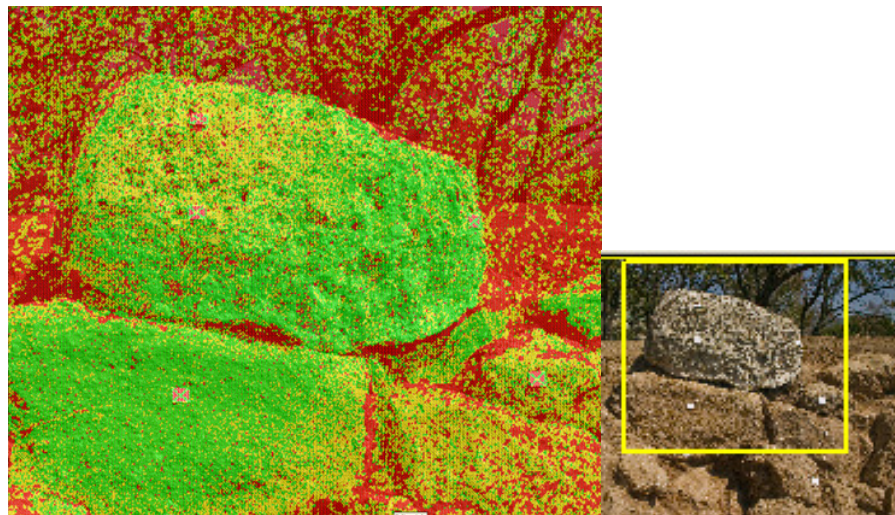


Figure 6: Result of the image matching indicated by colored pegs (2011)

Most of the problems during the photogrammetric processing were due to insufficient contrast in the images or areas on the images with too much shadow. Moreover, the rough terrain caused sometimes non-ideal image recording positions or a large scale difference between both images of the stereo couple. These problems were mostly solved during processing by for example manually adding extra homologous points during the relative orientation.

Digital elevation models are an accurate and detailed three dimensional reconstruction of buildings, monuments or archaeological sites. They form a strong and easily comprehensible visualization and a metric tool for scientists, visitors and outsiders. For the acropolis walls, the orthophotos are also combined in a CAD software, so they show a 3D reconstruction of the remnants of the acropolis walls.

Structure from motion and multi view stereo

During the field campaign in 2011, the remnants and foundations of the presumed temple of Asclepius were also recorded with digital overlapping images to make 3D models based on the combination of structure from motion and multi view stereo techniques (6, 7). These images were also systematically taken with 60 to 80% overlap and some of the ground control points for the photogrammetric restitution were also used in this processing to georeference the resulting 3D models and orthophotos in the Greek HGRS'87 coordinate system.

The processing was performed in the Agisoft PhotoScan software. During the following processing steps, a series of images is first automatically aligned based on corresponding points. In this step, the recording positions of all images are also calculated and reconstructed (Figure 7). The identification of the ground control points ('markers') resulted in an average error on all models of 6.5 to 8.0 mm (in X, Y and Z). In a next step, the geometry is built, resulting in a meshed surface of the recorded remnants. In the last step, the high resolution pictures are projected onto the meshed surface, resulting in a 3D model with high resolution texture. Based on the 3D models, orthophotos can be derived.

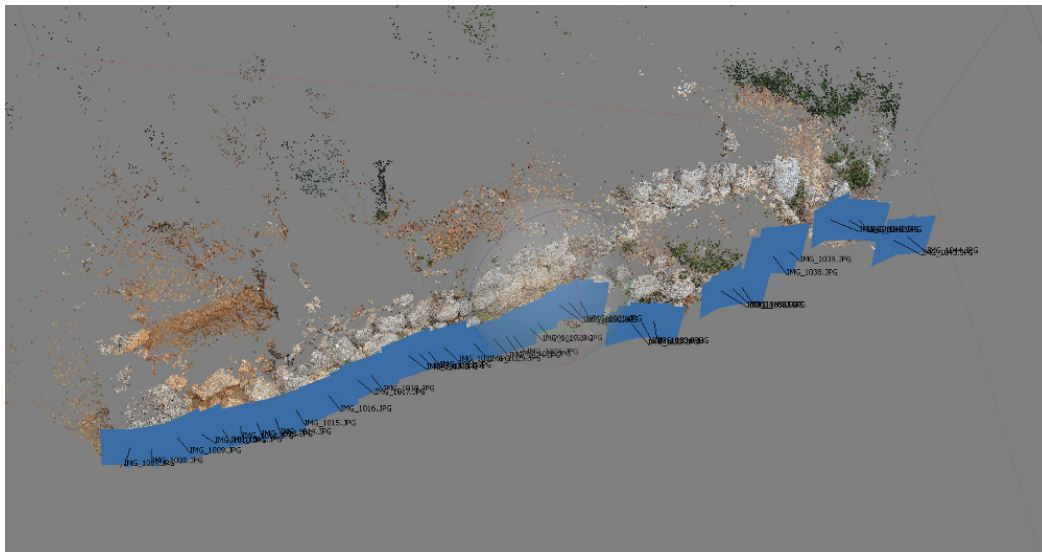


Figure 7: Structure from motion (Agisoft PhotoScan) – corresponding points and reconstructed image recording positions

The important advantage of this modelling technique is that most of the processing steps are completely automated so less labour intensive. The deliverables give very good visual results (Figure 8) combined with the required accuracy and can so be used to complement the 3D metric documentation of the site.

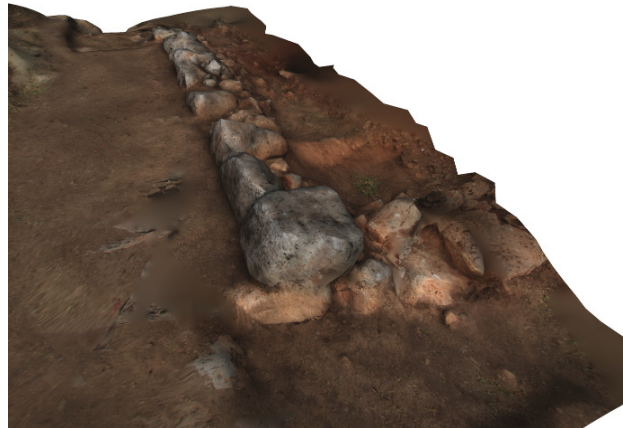


Figure 8: Agisoft PhotoScan – resulting 3D model of part of the remnants

CONCLUSIONS

The wide range of applied 3D measurement and modelling techniques results in a set of digital elevation models, orthophotoplans and a 3D virtual reconstruction of the archaeological site of Titani. These data sets are an important metric data source for archaeologists for the documentation, conservation and restoration of the site and the remnants on site. A recent collapse of a part of the wall on the acropolis proved the importance of such accurate metric information.

All measurements and deliverables are georeferenced in the Greek HGRS'87 coordinate system, using a geodetic point on top of the acropolis and own materialized reference points spread over the site during the different fieldwork campaigns. Most problems in the mapping and reconstruction process occurred during recording of the photogrammetric images and the photogrammetric processing. A lot of the problems were due to large contrast differences in the images, non-ideal viewing and recording points on the rough terrain or too large scale differences between two images of a stereo couple. For most of these problems, solutions were found such as manually identifying extra homologous points between two images of a stereo couple.

During the different fieldwork campaigns and the processing of the measurements afterwards, the large added value of combining different measurement and recording techniques was demonstrated. To cover the whole site and its surroundings and to meet all requirements for the deliverables, the combination of all mentioned techniques was essential. Moreover, as new techniques such as scanning and photomodelling came up during the projects time frame, these techniques were also tested and applied within the archaeological project.

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